Farm Technological Change and Farm Land Prices : Postwar Japan

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1. Introduction

One of the most significant changes in postwar Japanese agriculture is that farm land prices have increased very remarkably. According to the survey of farm land prices by Nihon Futosan Kenkyusho (Japan Real Estate Institute), paddy field prices have increased by 5.4 times over the period 1955-1975, while the consumer price has increased by 3.3 times over the same period.

The rapid increase of farm land price has invited a great anxiety among many agricultural policy-makers and economists, since high farm land prices could work as a serious obstacle against structural improvement in agriculture and result in increasing farm product prices.

The popular explanations for the increase in farm land prices are: 1) increase in output prices (particularly, supported rice prices) and yield per acre, and 2) increase of non-farm purpose demand, derived from speculative and asset-making motives. By the mid 1960s, it was generally accepted that farm land prices are determined by land income per acre, and the prime concern in the theory of farm land prices was how to estimate the land income per acre.[1] However, after the mid 1960s, farm land prices started to increase at a higher rate than previous periods in spite of the distinct decline in land income (figure 1). The apparent paradox led the theory of land prices to the second explanation —— an increase of non-farm purpose demand which was derived from speculative and asset-making motives.[2]

While each of these must be important in determining farm land prices, viewed from the stand-point of production economics, technological change must be also accounted as an important factor in farm land price movement. Herdt and Cochrane (1966) presented a theoretical formulation to explain the effect of technological change on farm land prices, and obtained the conclusion from an empirical analysis that technological change was the most important factor in contributing to the rise of farm land prices in the 1950s in the U.S.. However, since their theoretical formulation was developed in an intuitive fashion, they failed to present a structural relationship between farm land prices and technological change. Therefore, their discrimination in the theoretical formulation between neutral and biased technological change became meaningless in the empirical analysis when using the USDA's productivity index as the variable representing technological change.

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1) For example, Shirakawa (1961), Nakamura (1966), and Tsuchiya (1978).

2) For example, Sakamoto (1968), Kajii (1979), and Shimiz (1978).

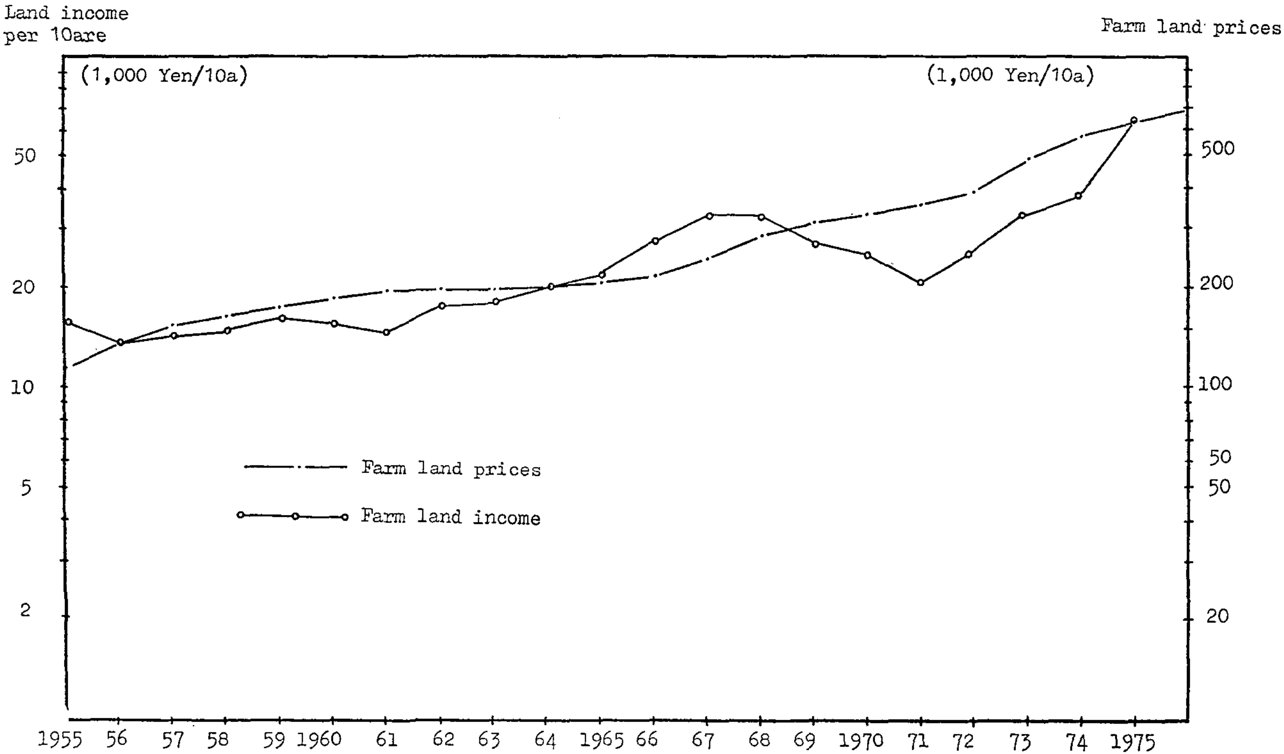

FIGURE 1

FARM LAND INCOME AND FARM LAND PRICES

Source: Land income from the Survey of Rice Production Cost, and farm land prices from the Survey of Farm Land Prices and Rent (Nihon Fudosan Kenkyusho).

In this paper, we present a theoretical framework to analyse farm land prices with special reference to technological change. Our plan is as follows. Changes in market prices of farm land are converted into changes in *total demand*[3] for farm land. The demand for farm land is then associated with shift in the marginal value productivity (MVP) function of land. Incidentally, speculative and asset-making motives are also taken as important factors in farm land demand. The shift of the MVP function is decomposed analytically into four factors: technological change biases, changes in total efficiency, changes in the quantities of the other factor inputs, and changes in output price. Then, a partial adjustment process is incorporated to link the actual and theoretical demand as is used in investment analysis.

By applying this model to postwar Japan, we intend to gain further insight into the structure of farm land prices in Japanese agriculture.

2. Theoretical Formulation

A) Determination of Farm Land Prices

The price equation is usually derived from the market demand-supply model in a price analysis. However, the so-called Wicksteed formulation shows that farm land prices may be looked upon as being determined from the demand side and so unrelated to supply factors.[4] In figure 2, let A and q be land and its prices per acre respectively, and let $\bar{A}$ be the total area available from the constant stock. Then, the market demand function D_M is drawn as conventionally. The reservation demand function D_R of the present holders can also be drawn in the same manner as the market demand function. Since the total available stock of land is fixed, the supply function is autonomously determined as $(\bar{A}-D_R)$,

3) *Total demand* denotes the summation of market and reservation demand.

4) Bronfenbrenner (1971), pp. 350-352.

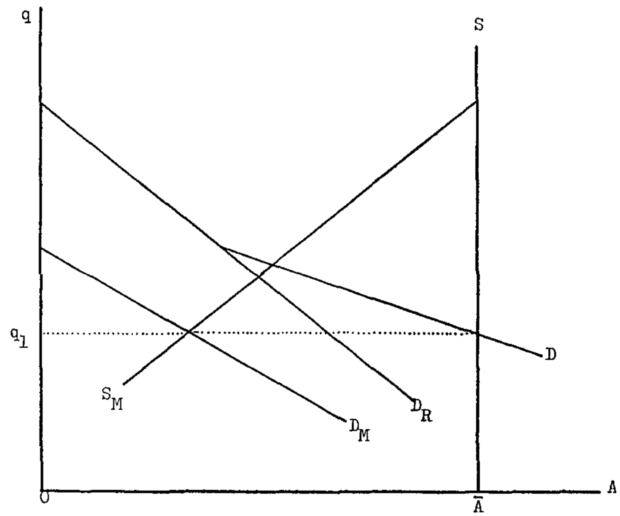

FIGURE 2
DETERMINATION OF FARM LAND PRICES

Notes: q —Farm land price,
A—Farm land area, $\bar{A}$—Fixed stock of farm land,
D_M—Market demand function,
D_R—Reservation demand function of present holders,
D —Total demand function (D_M+D_R),
S —Total supply function,
S_M—Market supply function ($S-D_R$).

and total aggregated demand is given by (D_M+D_R). As is clear from the diagram, the market land price is set at q_1, and at the same level, the total aggregated demand and total supply function intersect. Accordingly, the market price analysis of farm land can be carried out in the context of total aggregated demand and fixed supply. Also, the Wicksteed formulation implys that the market prices of farm land would change at the same rate as the shift of the total demand function:

(1) $\hat{q}_t=\hat{D}_t$

where the notation *hat* denotes the rate of change of the corresponding variable.

B) Farm Land Demand

Viewed from the theory of production, the demand for farm land is derived from the MVP function of land. When the MVP function which a farmer with a given land area has faced *shifts* upward, the farmer would claim a new piece of land in the farm land market, and thus his total demand, including both the reservation demand for his present area and the new demand in the market, would increase. On the contrary, when the MVP function *shifts* downward, his total demand would decrease.

We can thus take liberties to formulate a functional relationship between the individual demand for farm land and a shift of his MVP function of land as follows:

$$(2) \quad \hat{d}_i = \sum_j \beta_{ij} \hat{m}_{ij} \qquad i=1, \ldots, p$$

where $\hat{d}_i$ denotes the rate of change in total farm land demand of the i-th farmer, $\hat{m}_j$ the rate of shift of the MVP function, and β_j are unknown structural parameters. Since this relationship can be extended to the aggregated demand without deterioration, the rate of change in total aggregeted demand at a particular moment in time is given by

$$(3) \quad \hat{D}_t = \sum_j \beta_j \hat{m}_{jt}.$$

The parameter β_j can be taken as a demand elasticity of land with respect to the shifting factors of the MVP function. We will designate the $\hat{m}_j$ productive factors, since they are associated with the MVP function.

As already pointed in the introductory section, speculative and asset-making motives may have a significant effect on the demand for farm land. And thus, equation (3) is extended as follows to take into account such factors:

$$(4) \quad \hat{D}_t = \sum_j \beta_j \hat{m}_{jt} + \sum_j \gamma_j \hat{n}_{jt}$$

where $\hat{n}_j$ stands for the j-th non-productive factor. They are designated non-productive factors since they are not related to farm production.

Equation (4) represents the theoretical demand. However, there are costs involved in changing farm land area. That is, there are usually substantial transaction costs — searching, waiting, funding, and contracting costs. Furthermore, an expansion of farm land area usually requires a corresponding increase of labor and capital inputs. The supply of farm labor is very inelastic for an individual farm, particularly when farm worker migration and off-farm employment proceeds at a high rate. Also, an expansion of capital has to take its own adjustment process as have been well shown in many investment analyses.

The above consideration leads us to the postulation that the actual demand for farm land would take a partial adjustment process. Hence, we set[5]

$$(5)\quad \hat{D}_t - \hat{D}_{t-1} = \delta(\hat{D}_t^* - \hat{D}_{t-1}) \qquad 0<\delta<1$$

where δ stands for the adjustment coefficient and thea sterisk denotes the theoretical value. Therefore, we have the actual demand equation:

$$(6)\quad \hat{D}_t = \delta \sum_j \beta_j \hat{m}_{jt} + \delta \sum_j \gamma_j \hat{n}_{jt} + (1-\delta)\hat{D}_{t-1}.$$

From the result of the previous section: $\hat{q}_t = \hat{D}_t$, the demand equation (6) is converted into a price equation:

$$(7)\quad \hat{q}_t = \delta \sum_j \beta_j \hat{m}_{jt} + \delta \sum_j \gamma_j \hat{n}_{jt} + (1-\delta)\hat{q}_{t-1}.$$

C) Decomposition Theory of the MVP Function

We now turn to the development of a method to decompose a shift of the MVP function into a variety of factors within the context of production economics. Consider a production function,

$$(8)\quad y = f(x_1, \ldots, x_n, t)$$

where y stands for output, x_i for factor inputs, and t for time as a proxy for technological status at a particular moment in time.

5) The postulation is equivalent to
$\hat{D}_t^* = W_0\hat{D}_t + W_1\hat{D}_{t-1} + W_2\hat{D}_{t-2} + \cdots$
where $W_i = \delta(1-\delta)^i$. See Johnston (1972, p. 302).

We assume that the production function is twice differentiable, homogeneous, and well-behaved in a relevant range. Let the subscript, 1, stand for land in the following development.

From an elementary production theory, the marginal value productivity of land is given by

$$(9)\quad m = pf_1$$

where p stands for output price and $f_1 = \frac{\partial y}{\partial x_1}$. The rate of change in the MVP is thus

$$(10)\quad \hat{m} = \hat{p} + \hat{f}_1.$$

Meanwhile, the MVP function is given by

$$(11)\quad f_1 = f_1(x_1, \ldots, x_n, t).$$

Taking the logarithmic total time derivative, we have the rate of change in the marginal productivity of land:

$$(12)\quad \hat{f}_1 = \frac{1}{f_1}\sum_i f_{1i}\dot{x}_i + \frac{f_{1t}}{f_1} = \sum_{i=2} s_i c_{1i}\hat{x}_i + s_1 c_{11}\hat{x}_1 + \frac{f_{1t}}{f_1}$$

where $f_{1i} = \frac{\partial f_1}{\partial x_i}$, $f_{1t} = \frac{\partial f_1}{\partial t}$, and $c_{1i} = \frac{eff_{1i}}{f_1 f_i} = c_{1i}^* - (e-1)$.

Note that c_{1i}^* are the Hicks partial elasticities of complementarity (HEC) between land and other factors.[6]

On the other hand,[7]

$$(13)\quad \frac{f_{1t}}{f} = \frac{s_{1t}}{s_1} + \frac{f_t}{f}$$

where s_1 stands for the cost share of land input, and $s_{1t} = \frac{\partial s_1}{\partial t}$.

Substituting these results into (12), we obtain

$$(14)\quad \hat{f}_1 = \sum_{i=2} s_i c_{1i}\hat{x}_i + s_1 c_{11}\hat{x}_1 + \frac{s_{1t}}{s_1} + \frac{f_t}{f}.$$

Note that, according to the established definitions, the first term on the right side indicates the effect of other factor inputs on the MVP of land (designated intensity-factor, I-factor), the second reflects that of change in land area (designated size-factor), the third stands for that of biased technological change (designated bias-

6) Lee (1979b).

7) Lee (1979c).

factor, B-factor), and the last term is that of total efficiency increase (efficiency-factor, E-factor). Of the four factors, I-, B-, and E-factors work as shifting factors of the MVP function. Hence,

(15) $\hat{m}_{jt}=\{\hat{p}_t,\ I_t,\ E_t\ B_{it}\}$.

It is worthwhile nothing that the intensity factor absorbs the effects of other factor prices and/or farm worker migration. For example, farm worker migration would result in a change in labor input and thus a downward shift of the MVP function.

3. Empirical Result

A) Estimation of the Productive Factors

Method

The previous chapter showed that a shift of the MVP function can be neatly decomposed into four factors, and that we have to estimate the HEC, technological change biases, and total efficiency change to carry out the decomposition. They can be easily estimated in the most general fashion by estimating the translog production function.

The translog production function is defined as

(16) $$\ln y=a_0+\sum_i a_i \ln x_i+\frac{1}{2}\sum_i\sum_j b_{ij}\ln x_i \ln x_j$$

where $b_{ij}=b_{ji}$. If the production function is homogeneous, the following restictions hold:

(17) $$\sum_j b_{ij}=0 \quad \text{and} \quad \sum_i a_i=e$$

where e stands for the scale elasticity of the production function. The estimates for the b_{ij} coefficients can be converted into a point estimate of the HEC utilizing the following equations:

(18) $$c_{ij}^*=(\frac{b_{ij}}{e_i e_j}+1)\ e \qquad c_{ii}^*=(\frac{b_{ii}}{e_i^2}-\frac{1}{e_i}+1)\ e$$

where e_i denote the output elasticities.

Meanwhile, the degree of technological change bias is mea-

8) Lee (1979c)

sured in the translog production function[8] as follows:

$$(19)\quad B_1 = \hat{s}_1 - \frac{1}{e_1} \sum_i b_{1i} \hat{x}_i .$$

Also, total efficiency change can be measured in the conventional way, that is, total efficiency change at a particular moment is

$$(20)\quad E = \hat{y} - \sum_i s_i \hat{x}_i .$$

The intensity factor can be computed using the b_{ij} coefficients of the translog production function and cost shares: Substituting the equations (18) into the intensity factor term in equation (14), we have

$$(21)\quad I = \sum_{i=2} \left(\frac{b_{1i}}{e_1} + e_i \right) \hat{x}_i .$$

Data

Farm records from the Survey of Rice Production Cost during the period 1955-1975 provide the data for the estimation of the production function. The sample design of the survey is based on the results of the Census of Agriculture and Forestry and altered once every seven years or so in order to sustain the representativeness of the sample.

We selected four prefectures among which very clear contrasts are observed in average farm size and farm wage rates: Akita, Toyama, Aichi and Shimane. About one-third to one-half of the farms surveyed by Ministry of Agriculture and Forestry of Japan were randomly re-selected in each prefecture each year. This provided about 150 cases per year, and the total sample size was 2950 cases.

Output was measured in weight of brown rice. Input was categorized into four factors: land in cropped area (A); labor in adult-man-hours directly used for rice production (L); current goods, including fertilizer, pesticides and others in Yen (F); and machinery in terms of service flow in Yen (K). Machinery service consists of depreciation and interest on the value of machinery capital, fuel expenditure, sixty percent of custom work hired, and estimated expenditure on draft cattle service. Depreciation figures were obtained from the farm records. Forty percent of custom work hired was divided by the wage rate in the same prefecture, and then added to labor hours. All values were measured at 1970 constant prices, and all variables were transformed to geometric mean units for convenience. The methods of measuring the factor inputs are discussed in detail in Lee (1979a).

Expenditure on labor, current goods and machinery inputs are obtained directly from the farm records. Special care, however, was allocated to computing the expenditure on land. In the Survey of Rice Production Cost, the expenditure on land is estimated with the actual payment for the leased paddy field in the same area. The actual payment, however, had been much lower than the "real" price of the land service until 1967 or so, because the level of rent had been controlled at a very low level by the Farm Land Law. As a result, the payment in the survey jumped remarkably between 1966 and 1967 when the Farm Land Law was reformed to increase the legal rent by four times. Therefore, the trend in the data was extrapolated from 1967-1970 to inflate the data of 1955-1966 in a parallel motion.

Estimation of the Production Function

For the actual estimation, three years were set as one unit time, that is, the data period (from 1955 to 1975) was segmented into seven time units. Then, the following model was applied to the farm data to estimate the coefficients of the translog production function.

$$(22)\quad \ln y = \alpha_0 + \sum_{k=2}^{4} F_k + \sum_{t=2}^{7} H_t + \sum_{t=1}^{7} \sum_{i=1}^{4} a_{ti} \ln x_i + \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} b_{ij} \ln x_i \ln x_j + u$$

where k refers to the k-th prefecture, and t stands for time. F_k and H_t are intercept dummies incorporated in order to take into account neutral differences in production efficiency among prefectures and among time units respectively. And a_{ti} are allowed to be different from one unit time to another in order to reflect non-neutral technological change in the period. The disturbance term u is assumed to follow the conventional ordinary least-squares assumption.

This function can be converted into factor share functions provided that the production function is linear homogeneous and that the marginal value productivities of factor inputs are equal to their prices. Then the factor share functions can be used to estimate the coefficients of the production function. Such assumptions, however, are not always acceptable, especially when we have to use micro farm data. Hence we estimated the translog production function directly from farm data on input and output with the OLS method.

The validity of the homogeneity restriction and non-neutrality in technological change were accepted for the same data by Lee (1979b) but the Cobb-Douglas specification was rejected. According to those test results, the homogeneous translog production function is used for estimating the coefficients b_{ij} and e.

However, the Pearson correlation matrix for our data was 732.2, which means the sampling variance of OLS estimates would be expanded by about 15.2 times compared with the orthogonal case. We concluded that OLS estimates suffer from serious multicollinearity, and that the ridge regression (RR) method is perferable in this case.

We define the ridge estimator of restricted linear regression as

$$\hat{b} = \hat{\beta} + (X'X + kI)^{-1}R'[R(X'X + kI)^{-1}R']^{-1}(r - R\hat{\beta}) \tag{23}$$

where $\hat{\beta} = (X'X + kI)^{-1}X'Y$, R and r stand for linear restrictions on the parameters β_{ij} and $r = R\beta$. Y is a vector of observation on the dependent variable, X is a matrix of regressors standardized in such a way that X'X is the non-singular correlation matrix, and k is a non-negative biasing factor.

The justification for applying RR in the case of restricted least-squares estimation is provided in Lee (1979b). And increment of biasing factor in RR was terminated when the Vinod's Index of Stability of Relative Magnitude (ISRM) revealed the minimum level.[9]

The ISRM is minimized at $k=0.10$ and R^2 is reduced by only

TABLE 1
PARAMETER ESTIMATES OF THE HOMOGENEOUS TRANSLOG PRODUCTION FUNCTION

Parameters	Estimates	Parameters	Estimates
a_{11}	0.5782 (0.0211)	a_{44}	0.0528 (0.0166)
a_{12}	0.1325 (0.0167)	a_{51}	0.4713 (0.0221)
a_{13}	0.2093 (0.0179)	a_{52}	0.2108 (0.0225)
a_{14}	0.0655 (0.0120)	a_{53}	0.2585 (0.0196)
b_{11}	−0.0025 (0.0078)	a_{54}	0.0447 (0.0148)
b_{12}	0.0112 (0.0058)	a_{61}	0.4662 (0.0182)
b_{13}	−0.0204 (0.0055)	a_{62}	0.1898 (0.0171)
b_{14}	0.0146 (0.0056)	a_{63}	0.2669 (0.0170)
b_{22}	0.0108 (0.0090)	a_{64}	0.0626 (0.0122)
b_{23}	−0.0075 (0.0062)	a_{71}	0.5339 (0.0176)
b_{24}	−0.0146 (0.0057)	a_{72}	0.1186 (0.0131)
b_{33}	0.0104 (0.0080)	a_{73}	0.2383 (0.0162)
b_{34}	0.0175 (0.0050)	a_{74}	0.0947 (0.0117)
b_{44}	−0.0145 (0.0065)	H_2	0.0153 (0.0121)
a_{21}	0.5566 (0.0199)	H_3	0.0206 (0.0116)
a_{22}	0.1545 (0.0181)	H_4	0.0127 (0.0104)
a_{23}	0.2209 (0.0172)	H_5	0.0570 (0.0105)
a_{24}	0.0535 (0.0139)	H_6	0.0013 (0.0120)
a_{31}	0.5237 (0.0225)	H_7	0.0512 (0.0126)
a_{32}	0.1707 (0.0208)	F_2	0.1778 (0.0092)
a_{33}	0.2153 (0.0191)	F_3	0.1145 (0.0090)
a_{34}	0.0758 (0.0178)	F_4	0.0381 (0.0094)
a_{41}	0.4951 (0.0232)	α_0	−0.1137
a_{42}	0.2047 (0.0228)	R-Squares	0.9105
a_{43}	0.2329 (0.0209)	k	0.10

a. k is the biasing factor in ridge regression.
b. The figures in parentheses are standard errors.
c. F_2 is for Akita, F_3 for Toyama and F_4 for Aichi prefecture respectively.

9) Vinod (1976).

0.042 in the homogeneous case. Therefore, we adopted the estimates at k=0.10 and present the estimated coefficients in table 1.

In addition, we investigated whether the estimated homogeneous translog function is well-behaved. The fitted output elasticities are positive for almost all observations. Furthermore, the bordered Hessian determinant of the estimated function is negative definite at almost all data points. Thus we conclude that our estimated homogeneous translog production function is appropriate to represent the state of technology of postwar Japanese agriculture.

Computation of the Productive Factors

Applying the estimated coefficients of the translog production

TABLE 2

ESTIMATED PRODUCTIVE FACTORS

Year	T-factor			I-factor	P-factor	Total
	B-factor	E-factor	Total			
(1955-57)						
	0.92	1.27	2.19	0.84	1.73	4.76
(1956-58)						
	0.97	2.64	1.67	0.67	−0.80	1.54
(1957-59)						
	0.48	1.84	2.32	0.74	−0.12	2.94
(1958-60)						
	0.00	1.52	1.52	−0.49	−1.06	−0.03
(1959-61)						
	−1.77	0.31	−1.46	−0.08	−1.30	−2.84
(1960-62)						
	−4.78	−0.02	−4.80	−0.03	−0.27	−5.10
(1961-63)						
	−4.57	0.18	−4.39	−0.24	1.22	−3.41
(1962-64)						
	−4.67	0.26	−4.41	−0.64	4.22	−0.83
(1963-65)						
	−2.84	−0.05	−2.89	−1.50	3.82	−0.57
(1964-66)						
	−2.48	0.54	−1.94	0.17	5.21	3.44
(1965-67)						
	−2.56	1.14	−1.42	1.32	4.24	4.14
(1966-68)						
	−2.22	−0.62	−2.84	3.62	3.12	3.90
(1967-69)						
	0.41	−1.36	−0.95	2.45	−0.41	1.09
(1968-70)						
	2.28	−0.55	1.73	1.54	−4.85	−1.58
(1969-71)						
	4.46	3.04	7.50	−0.53	−5.67	1.30
(1970-72)						
	4.47	3.07	7.54	−1.63	−3.74	2.17
(1971-73)						
	0.61	1.25	1.86	0.94	0.88	3.68
(1972-74)						
	1.27	1.46	2.73	2.35	5.18	10.26
(1973-75)						

function and the discrete difference between two consecutive three-year moving averages to the discrete forms of the equations (19), (21), and (20), we computed the three productive factors as shown in table 2.

Meanwhile, the output price factor (P-factor) was measured by the proportional changes between the two consecutive three-year moving averages of the farmer's real selling prices of rice. The farmer's selling prices were computed by dividing the total revenue by the total produced quantity.

The measured result shows that the B-factor, after a moderately positive period in the late 1950s. became a large negative quantity in the 1960s. From the late 1960s, this factor turned again to a substantial positive quantity. The E-factor shows a trend similar to the B-factor: large positive in the late 1950s, small and positive to negative in the 1960s, and again, large and positive in the late 1960s.

Meanwhile, the magnitude of the I-factor has been small as compared with the other factors. One may have expected the I-factor to be a large negative quantity because labor input has decreased at an impressive rate due to the rapid expansion of off-farm employment. However, close investigation showed that the effect of labor input decrease had been offset by machinery input increase to keep the I-factor neutral. This may imply that farmers have not sacrificed the land productivity for the sake of off-farm employment. The P-factor has fluctuated with a big amplitude whenever the government price policy changed.

B) Computation of the Non-productive Factor

Rapid urbanization and complex land-using development like highway and factory construction have an impact on land prices near such developments. By increasing the expected selling price of the farm land, non-farm purpose land demand increases the general price of farm land that a farmer may be willing to receive or pay at present. Furthermore, the expected gain is magnified in the midst of inflation. Interest, fund market, and trade-cycle also have an effect on farm land prices. As a variable reflecting all these non-productive factors, we choose the rate of change in the price of farm land used for house-building.

C) Estimation of the Price Equation

We now proceed to estimating the coefficients of the price equation. Exogeneous variables are provided by the previous two sections, and the dependent variable comes from the survey of farm land prices by Nihon Futozan Kenkyusho.

We tried two alternative models:

Model I : $\hat{q}_t = \delta\beta\hat{m}_t + \delta\gamma\,\hat{n}_t + (1-\delta)\hat{q}_{t-1} + u_t$

where $m_{1t} = B_{1t} + E_t + I_t + \hat{p}_t$.

Model II : $\hat{q}_t = \delta\beta_1\hat{m}_{1t} + \delta\beta_2\hat{m}_{2t} + \delta\gamma\,\hat{n}_t + (1-\delta)\hat{q}_{t-1}$

where $\hat{m}_{1t} = B_{1t} + E_t + I_t$ and $\hat{m}_{2t} = \hat{p}_t$.

Model II was tried to take into consideration the fact that the demand elasticities may be different between the technical and price factors. The estimated results are presented in table 3.

TABLE 3

ESTIMATED COEFFICIENTS OF THE PRICE EQUATION

Parameters	Model I	Model II
$\delta\beta$	0.4247 (0.1864)	
$\delta\beta_1$		0.4333 (0.2498)
$\delta\beta_2$		0.4207 (0.2072)
$\delta\gamma$	0.0262 (0.0485)	0.0268 (0.0515)
$(1-\delta)$	0.5640 (0.1249)	0.5600 (0.1378)
R^2	0.8522	0.8521

a. Model I $\hat{q}_t = \delta\beta\hat{m}_t + \delta\gamma\,\hat{n}_t + (1-\delta)\hat{q}_{t-1}$

Model II $\hat{q}_t = \delta\beta_1\hat{m}_{1t} + \delta\beta_2\hat{m}_{2t} + \delta\gamma\,\hat{n}_t + (1-\delta)\hat{q}_{t-1}$

b. Standard errors in parentheses.

Statistical properties of the estimates are reflected by R^2 and the standard errors of the estimates. The estimates of the coefficient of the non-productive factor have large standard errors in both models. However, the magnitude of the estimate shows a good stability against the modification of the estimation model and a small perturbation in the variable. Hence, we keep the estimate as a sensible coefficient.

Comparing the estimated results of the two alternative models, we are convinced that the demand elasticities are not different between the technical and price factors. Utilizing the definition, we computed the long run elasticities and the adjustment coefficient, and presented them in table 4 together with the short run elasticities. The adjustment coefficient is 0.4360. It may look very high at first. However, it should be noted in the interpretation of the magnitude that the adjustment coefficient is not for the actual change in cropping area but for the demand schedule.

TABLE 4
DEMAND ELASTICITY AND CONTRIBUTION ACCOUNTING

Factor	Elasticity		Contribution		
	Short-run	Long-run	Short-run		Long-run[c]
Productive factors	0.4247	0.9740	0.5857[a]	(65.2)	1.3429
T-factor			0.1472	(16.3)	0.3376
I-factor			0.2241	(25.0)	0.5140
P-factor			0.2144	(23.9)	0.4913
Non-productive factor	0.0262	0.0603	0.3121[b]	(34.6)	2.0613
Total			0.8978	(100.0)	2.0613

a. $\delta\beta\bar{m}_j$, the bar denotes arithmatic mean.

b. $\delta\bar{n}_j$ the bar denotes arithmatic mean.

c. Long-run contribution rates are same with the short-run.

Following convention, we accounted the relative contribution of each factor to the farm land price movement. One-third of the farm land price movement between 1955 and 1975 is ascribed to the non-productive factor and about twenty percent to each of the three productive factors. However, this accounting may be biased because values of the opposite sign may have been offset in computing the averages of the factors. Therefore, we proceeded to the simulation experiment to scrutinize the significance of each factor.

D) Simulation Experiment

To gain further insight into the sources of the farm land price movement, four experimental simulations were conducted. We proceeded as follows. First, the model will be simulated over the period 1955-1975 using the actual exogeneous variables for that period to provide a benchmark with which the experimental simulations can be compared. Then each of the four factors will be set at zero and the resulting simulation is contrasted with the benchmark run. The difference between the benchmark and experimental run represents the effect of the factor being kept zero.

The experimental results are presented in a diagrammatic form in figure 3. The benchmark run shows that our model underestimates the decreasing rate in the early 1960s by 2.0 to 2.5 percent. In spite of such an underestimation the benchmark run makes few errors in the direction of the price movement.

The first experimental run was conducted keeping the non-productive factor zero. The result shows that the non-productive factor has had a steady effect on farm land prices. But the effect was not dominant and even if the non-productive factor had not existed, the overall pattern of the change in farm land prices would not have changed.

As the second experiment, a simulation was carried out with zero price-factor in order to investigate the effect of rice price on farm land price. The remarkable increase of farm land prices would not have existed in the *late* 1960s if rice price had not increased at such a high rate in the *early* 1960s. On the contrary, farm land prices would have increased at a higher rate than the actual rate in the early 1970s if rice price had not decreased in

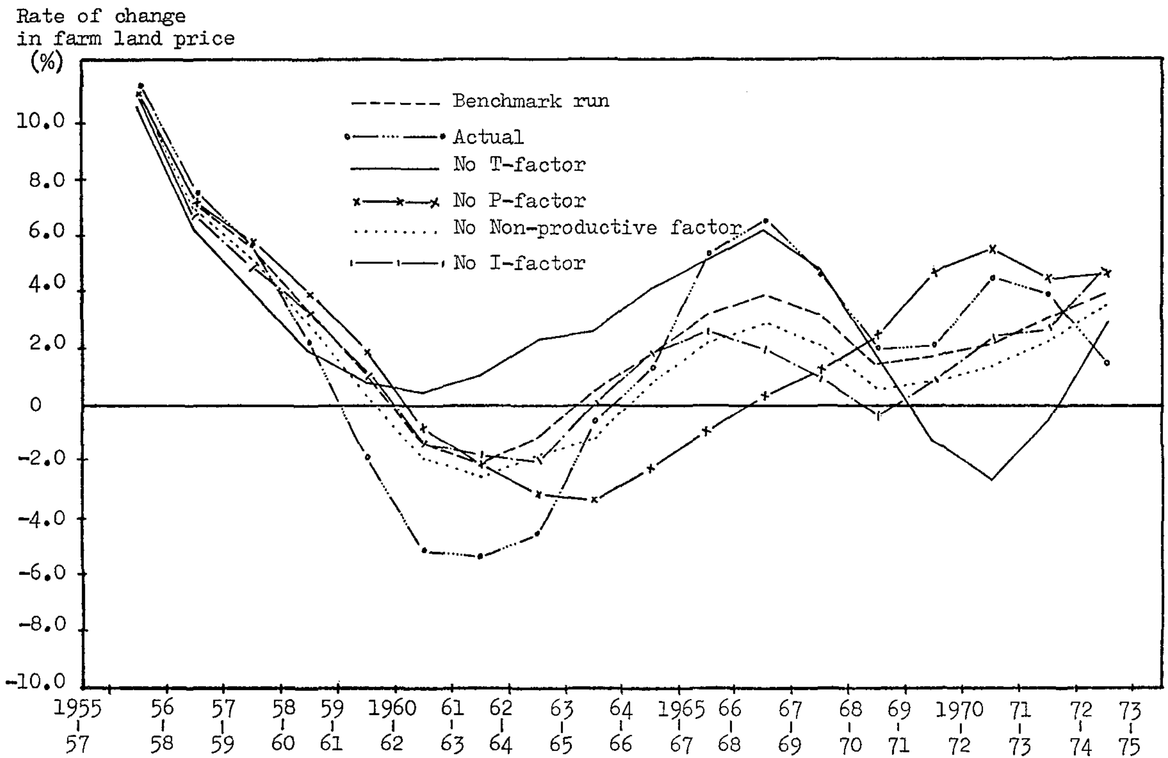

FIGURE 3
THE RESULTS OF SIMULATION EXPERIMENTS

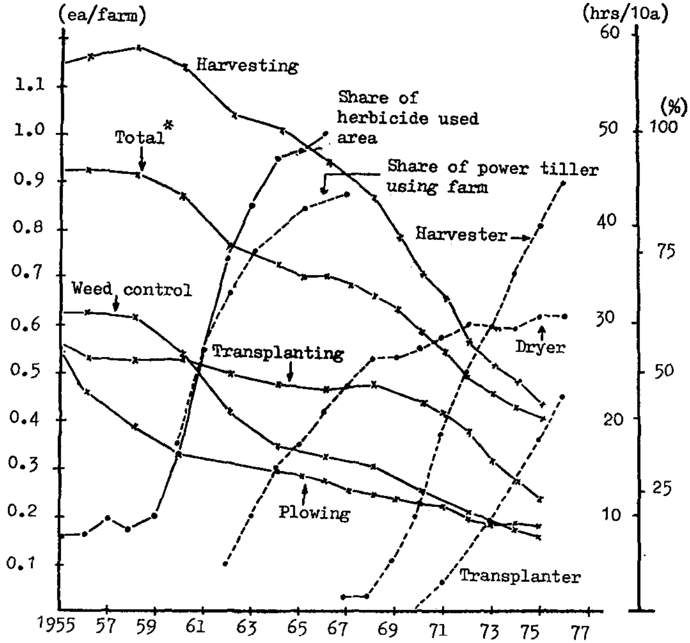

FIGURE 4

MACHINERY DIFFUSION AND LABOR HOURS IN POSTWAR JAPANESE RICE FARMING

*10hrs/10are

Source: (a) Herbicide——Norin Tokei Kyokai, Sengo Nogyo Gijutsu Hattatsushi, Suitosaku-hen, pp. 690-697.

(b) Machinery——Ministry of Agriculture and Forestry, Survey of Rice Production Cost (1955-1975), and Nogyo Chosa (1967).

the late 1960s.

The third experiment, which was for evaluating the effect of technological change, displays the fact that the effect of technological change was very striking. But for the factor of technological change, farm land prices would not have decreased in the early 1960s and would not have increased (rather, it would have decreased) in the early 1970s. This result will be made more defensible by an agronomic inspection for the rice growing techniques of the postwar period.

Up to the early 1960s, herbicide and power tiller were diffused at a progressive rate into the farming system, and the labor requirement for plowing and weed control, which had been heavy labor consuming tasks, declined rapidly (figure 4). This benefited larger size farms and thus provided an incentive to an expansion of

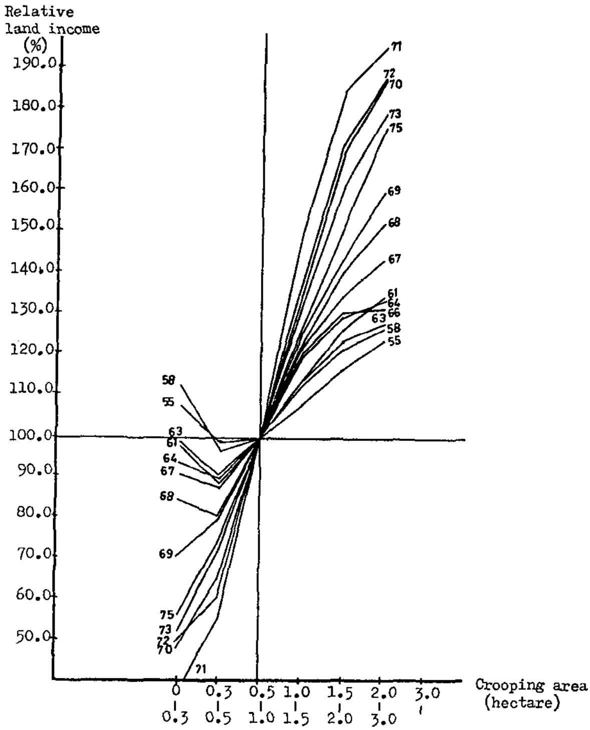

FIGURE 5

CHANGE IN DIFFERENTIAL STRUCTURE OF LAND INCOME

(a) Source: Ministry of Agriculture and Forestry, Survey of Rice Production Cost.
(b) Land income = Revenve − (Production cost − rent).
(c) Farm group over three hectare was excluded because the sample farms of the group were too biased toward one region (Hokkaido) to represent the farm group of Japan.

cropping area (figure 5). However, since the role of power tiller and herbicide was limited only to plowing and weed control, the expansion of farm size came to face a severe constraint in transplanting and harvesting in the early 1960s. This limitation let the rice farming boom, which was evoked by the rapid increase of rice price, associated with the yield-oriented techniques such as intensive pest control and very sophisticated fertilizer application and water control.[10] We can speculate safely that such a technological condition would have damped down the incentive to expand cropping area from the early to late 1960s (figure 5).[11] However, transplanting and harvesting machines were developed and came to be diffused in a widespread fashion from the late 1960s (figure 4). Accordingly, larger size farms came to gain advantage in the midst of the rapid increase of farm wages (figure 5).[12] We can speculate again that this technological condition would have stimulated new demand for farm land from the late 1960s.

As the final experiment, a simulation was conducted on the effect of the intensity-factor. The I-factor had a weak effect throughout the postwar period as expected from the result of section B.

4. Summary and Conclusions

Farm land prices increased very remarkably in postwar Japan. In the midst of the increase, however, there were two puzzling affairs in the actual movement. One is that the prices stagnated from the early to mid 1960s in the face of substantial increase of rice price, and the other is that, from the late 1960s, the prices

10) Sengo Nogyo Gijutsu Hattatsushi, Shokatsuhen (Norin Tokei Kyokai, 1971), pp. 99–103, pp. 108–109.
11) This is consistent with Ito's assertion that the stagnation of farm land demand was mainly due to technological limitation (Ito, 1979 and 1975) and Miyai's analysis that farm land prices decreased in the regions where large size farms had little advantage over smaller farms (Miyai, 1963).
12) Ito (1975) and Kajii (1979, pp. 103–122).

turned to a rapid increase despite the distinct decrease of rice price.

These seemingly contradictory states of affairs led us to an analysis of the farm land price movement with a special reference to technological change. Decomposing the land price movement into a few factors (four farm productive factors and one non-productive factor) by an analytical method, we were convinced that farm technological change, particularly, the type of bias could have an important effect on farm land prices.

Applying the theoretical formulation to postwar Japan, we found:

1) Speculative and asset-making motives were not dominant factors in the stated contradictory land price movement, even if they have worked as an important land price increasing factor.

2) Technological change was a decisively important factor in the farm land price movement. This was the major causative factor in the stagnation of the early 1960s and the increase of the early 1970s.

3) However, the rapid increase in the late 1960s is not ascribed to technological change but rather to the high rate increase of rice price in the early 1960s.

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